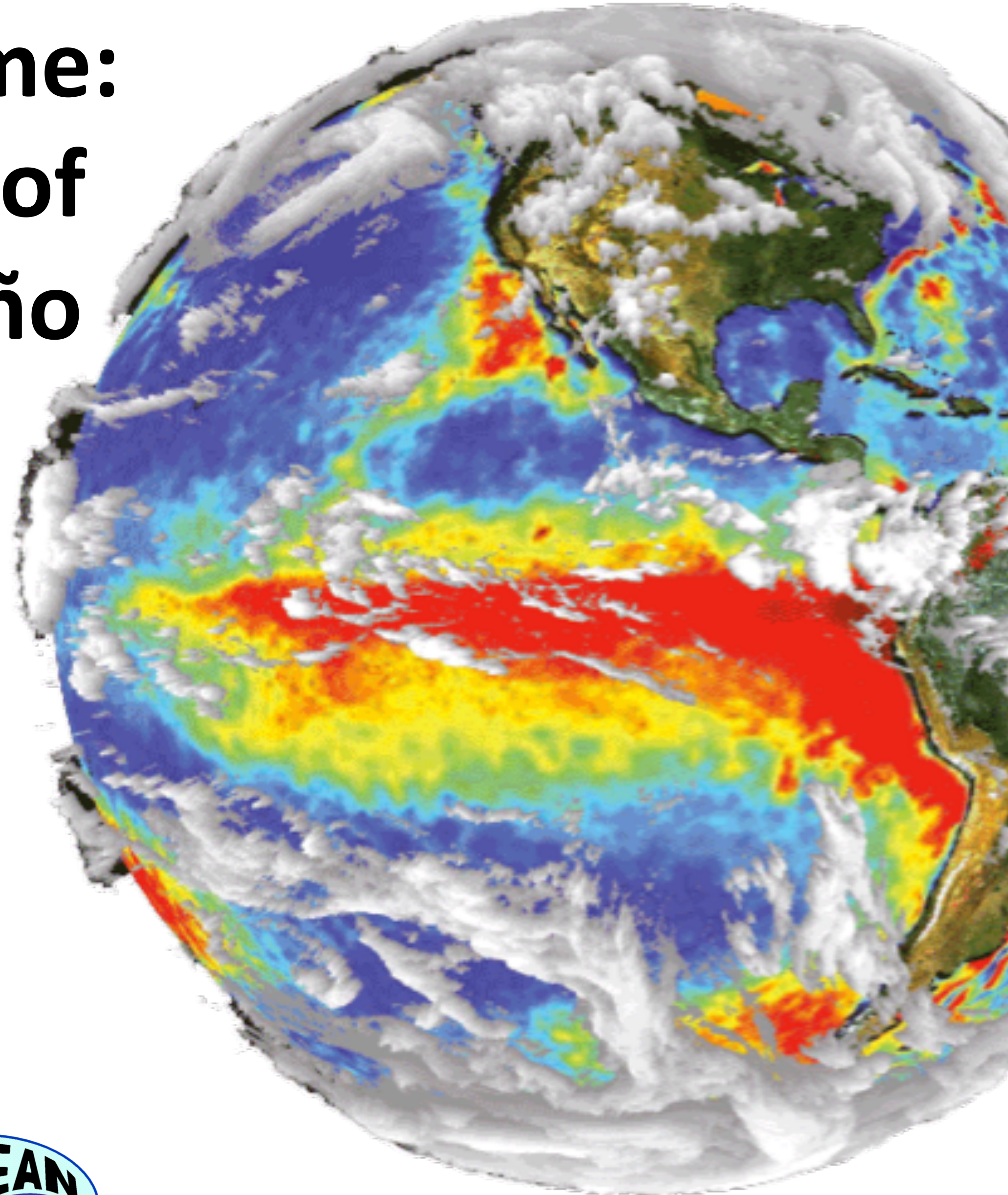
Warm Water Volume: a better predictor of La Niña than El Niño



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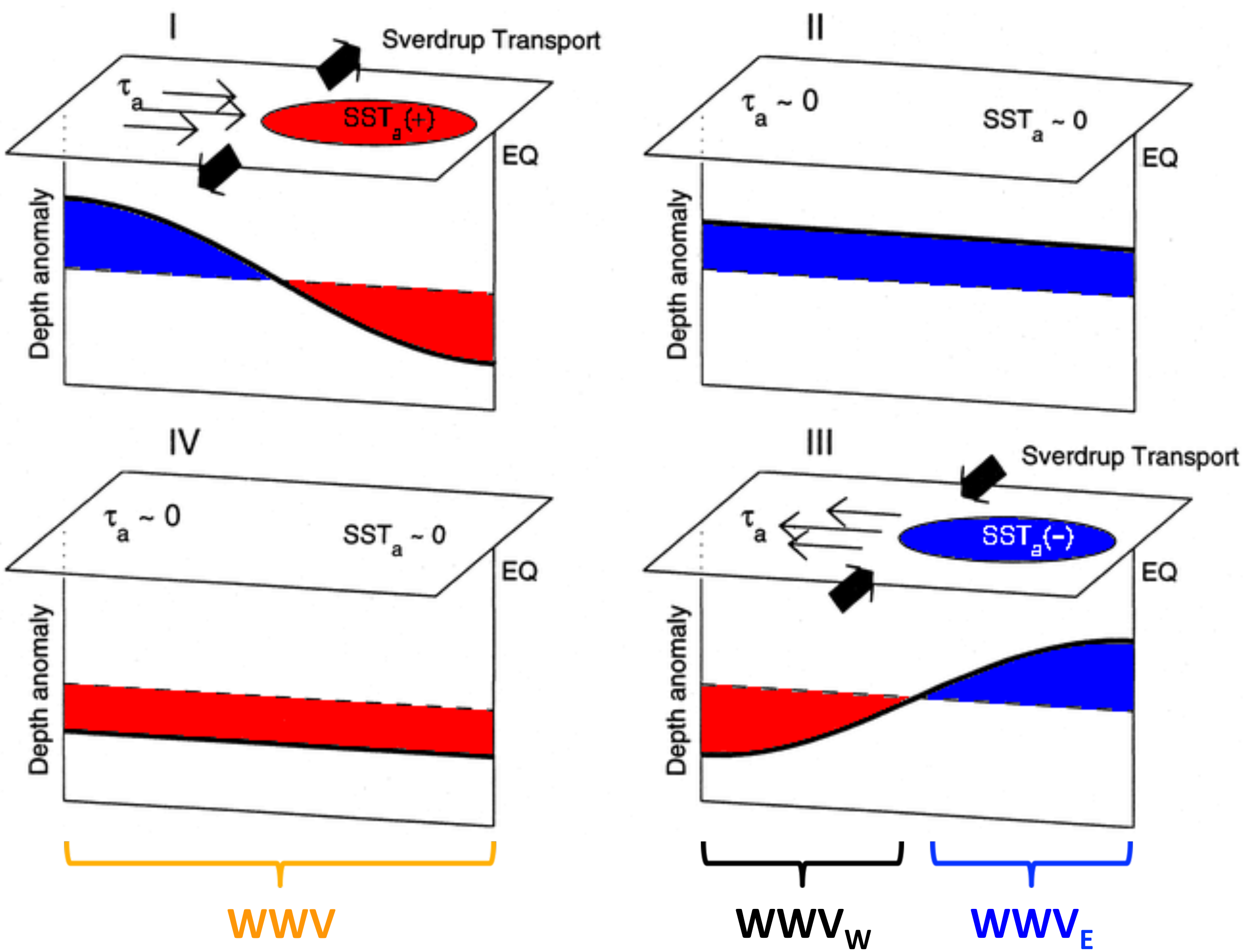
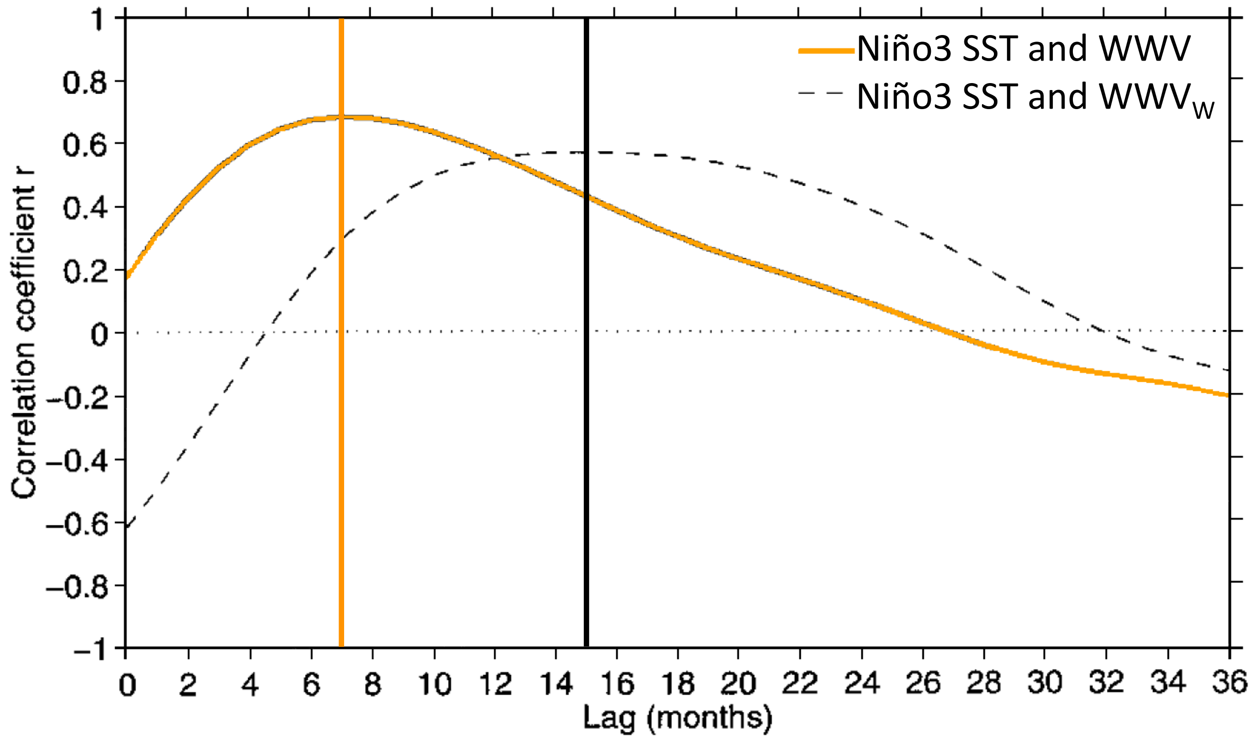
CNRS Sciences de l'environnement
Institut Pierre Simon Laplace
IRD Institut de Recherche pour le Développement FRANCE
LOCEAN

Recharge / discharge oscillator (Jin 1997)



Meinen and McPhaden (2000)

Warm water volume (WWV)

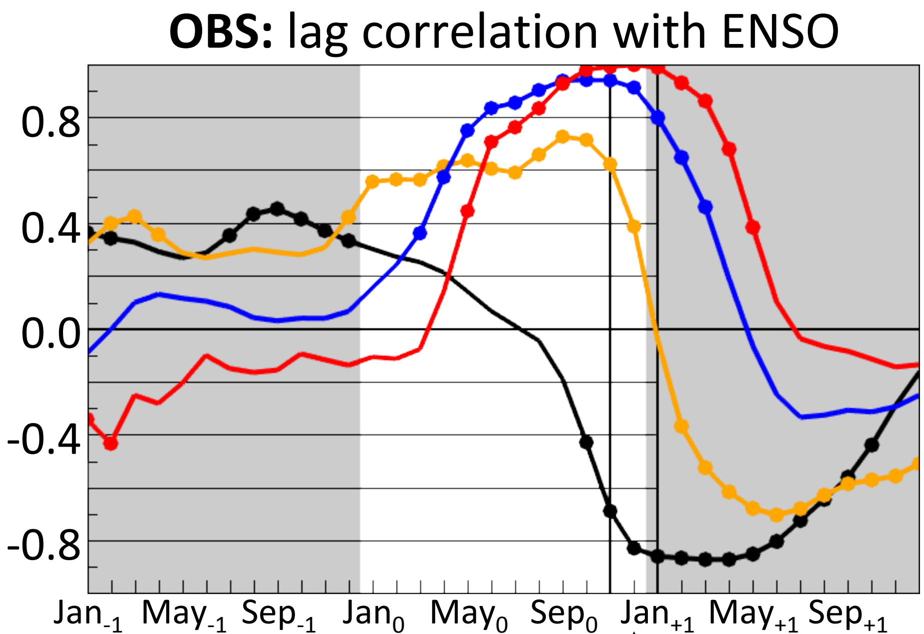


peak correlation with WWV at 7 months

peak correlation with WWV_W at 15 months

Meinen and McPhaden (2000)

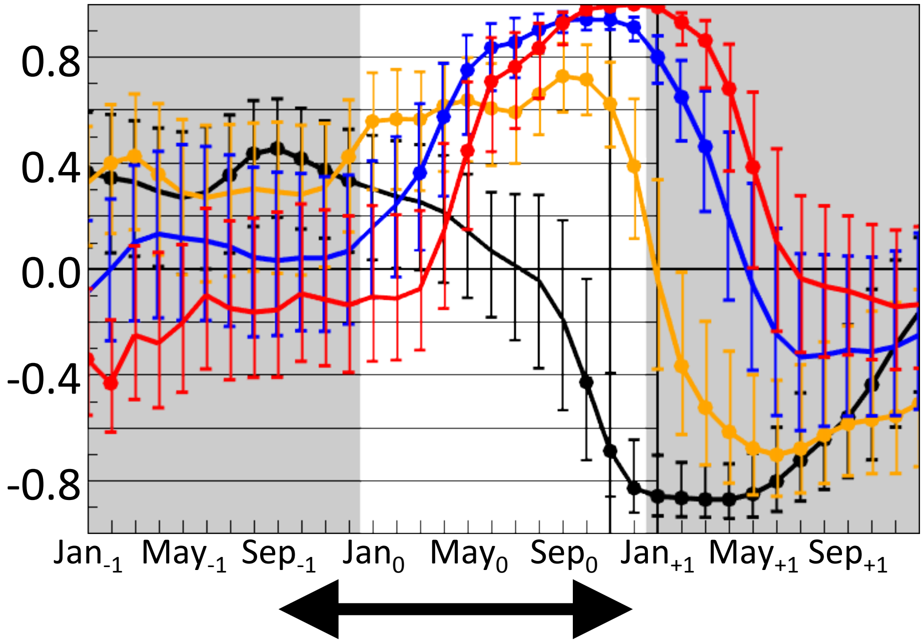
WWV_W: a precursor for ENSO



ENSO peak in NDJ

WWV_W: a precursor for ENSO

OBS: lag correlation with ENSO



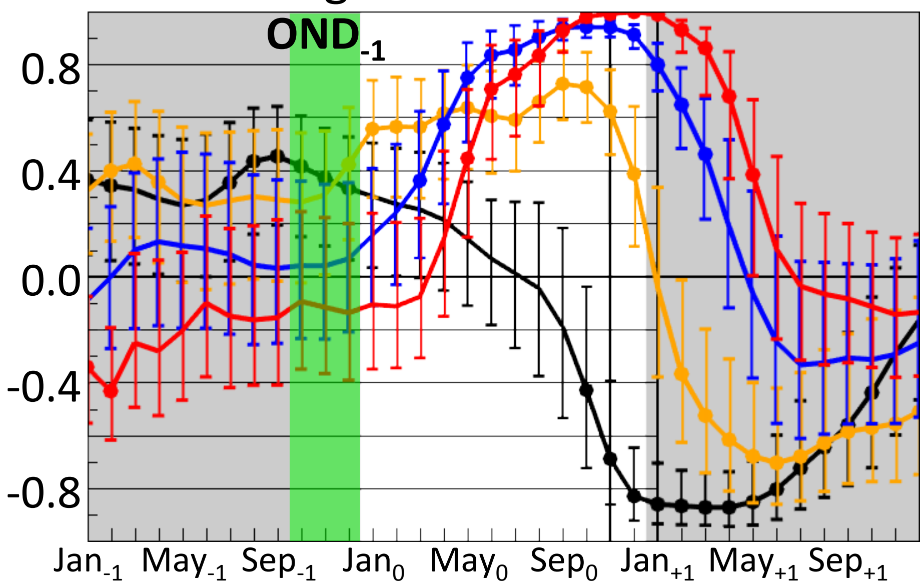
95% confidence interval

correlation with WWV_W peaks at 15 months (consistent with Meinen and McPhaden 2000)

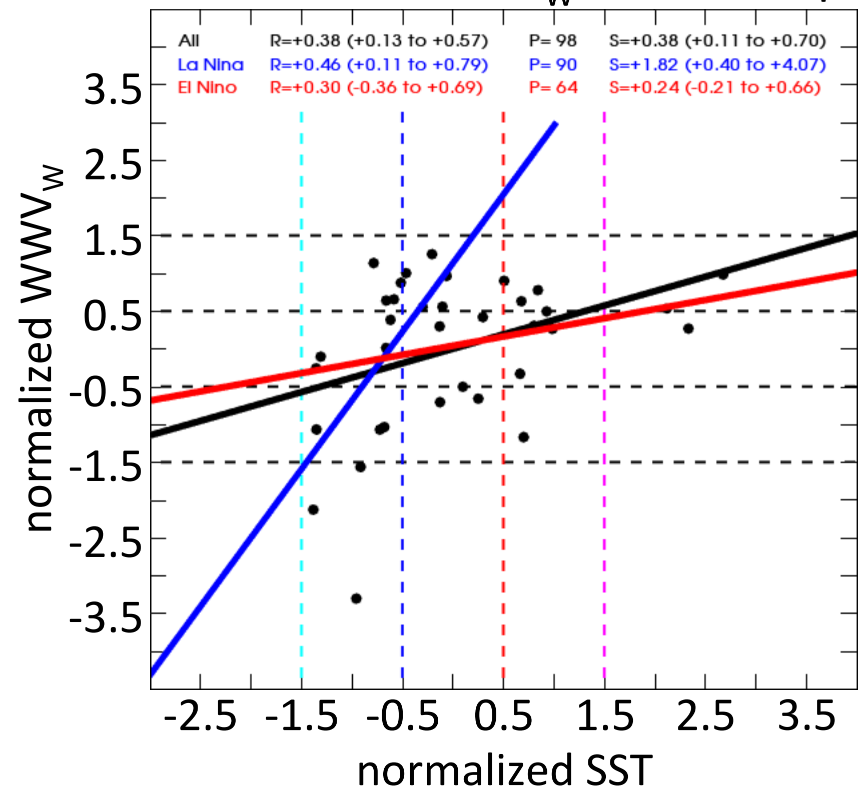
SST: **Niño3**
WWV: **equatorial Pacific**
WWV_E: **eastern equatorial Pacific**
WWV_W: **western equatorial Pacific**

WWV_W: a precursor for ENSO

OBS: lag correlation with ENSO



OBS: ENSO-WWV_W relationship

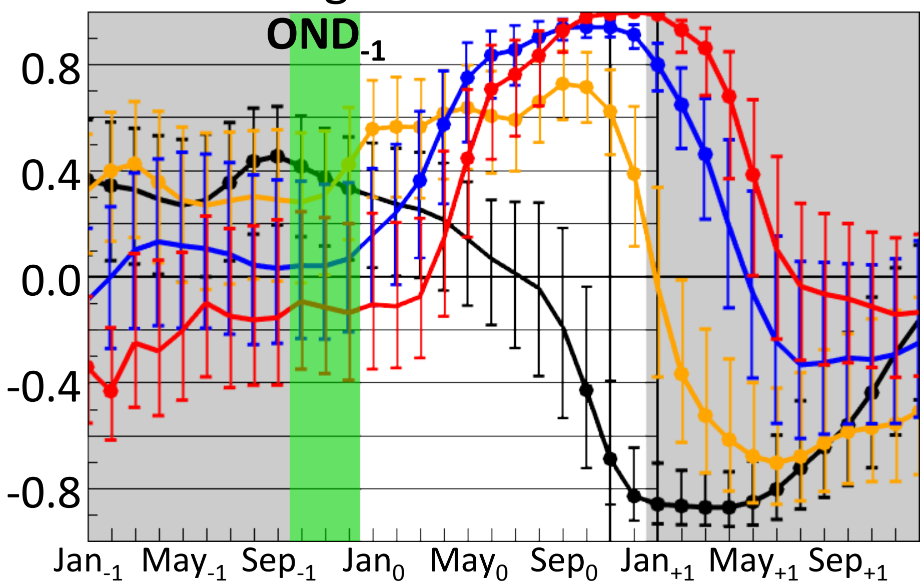


SST: Niño3
WWV: equatorial Pacific
WWV_E: eastern equatorial Pacific
WWV_W: western equatorial Pacific

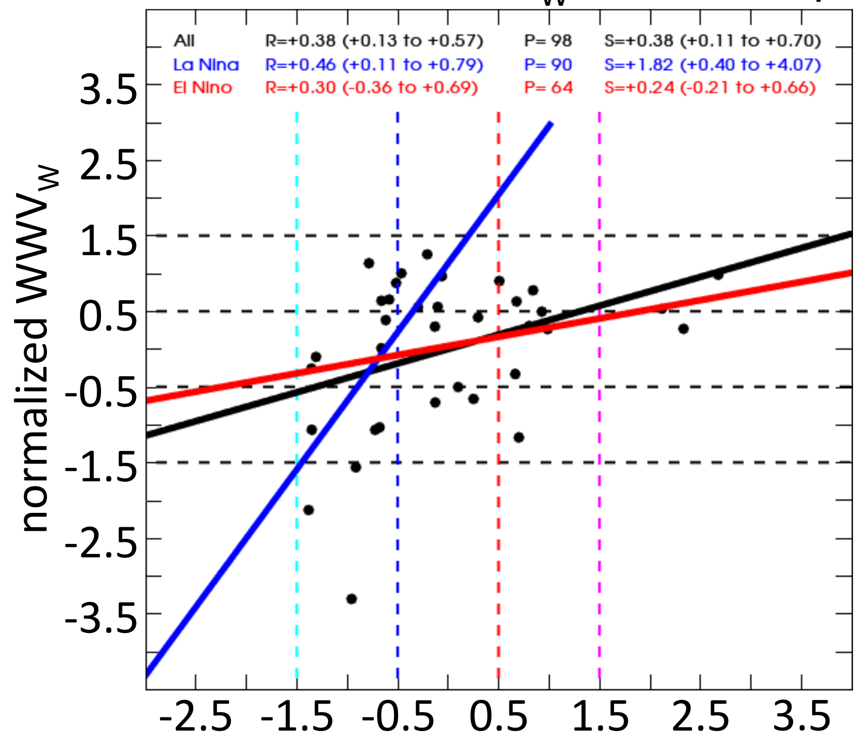
La Niña events: SSTA < -0.5 STD
El Niño events: SSTA > 0.5 STD

WWV_W: a precursor for ENSO

OBS: lag correlation with ENSO



OBS: ENSO-WWV_W relationship



slope of the linear regression

La Niña events: 1.82 (0.40 to 4.07)

El Niño events: 0.24 (-0.21 to 0.66)

➔ strong nonlinearity

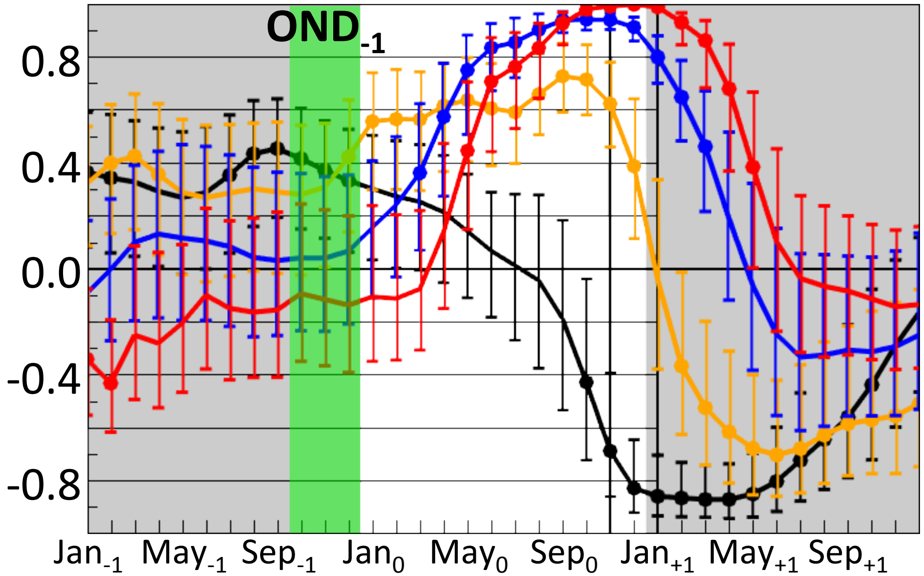
➔ but strong uncertainties (12 La Niña events, 11 El Niño events)

➔ Asymmetry in the WWV_W–ENSO relationship

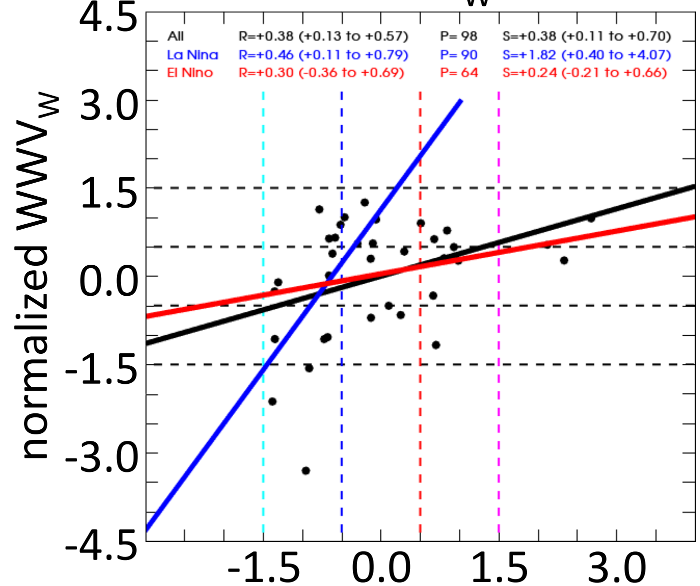
- Can CMIP5 models reproduce the asymmetry?
- How does the asymmetry affect ENSO prediction?
- How can we explain the asymmetry?

Asymmetry & CMIP5 models?

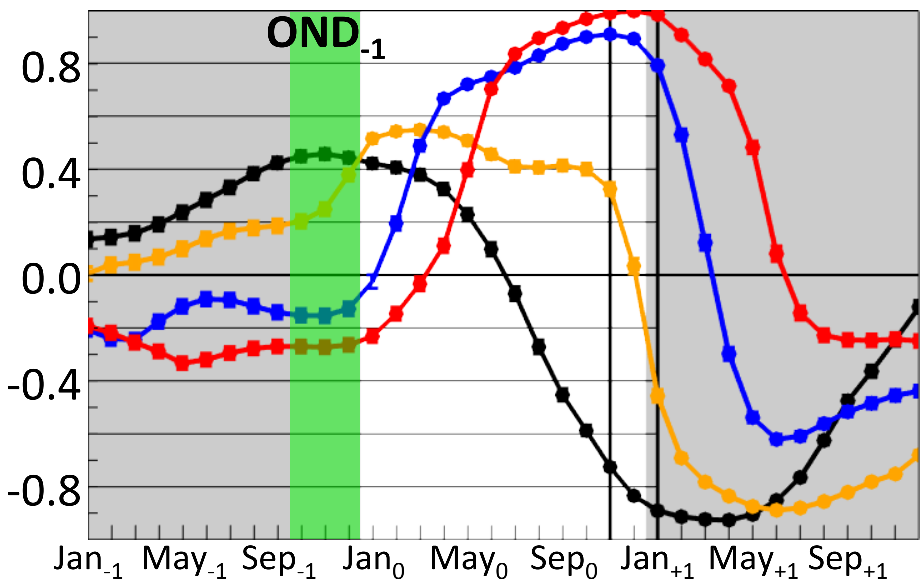
OBS: lag correlation with ENSO



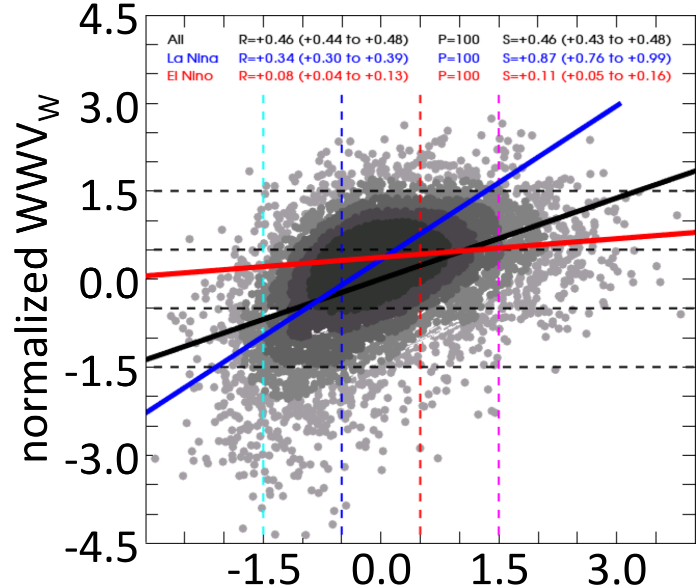
OBS: ENSO-WWV_W relationship



MME

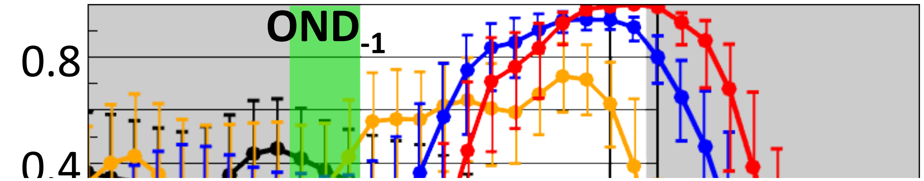


MME

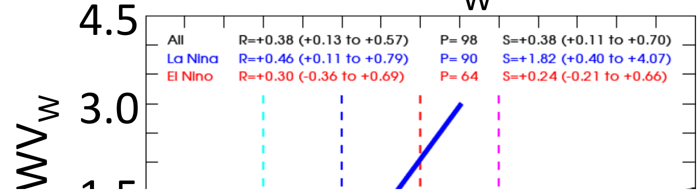


Asymmetry & CMIP5 models?

OBS: lag correlation with ENSO



OBS: ENSO-WWV_W relationship



slope of the linear regression

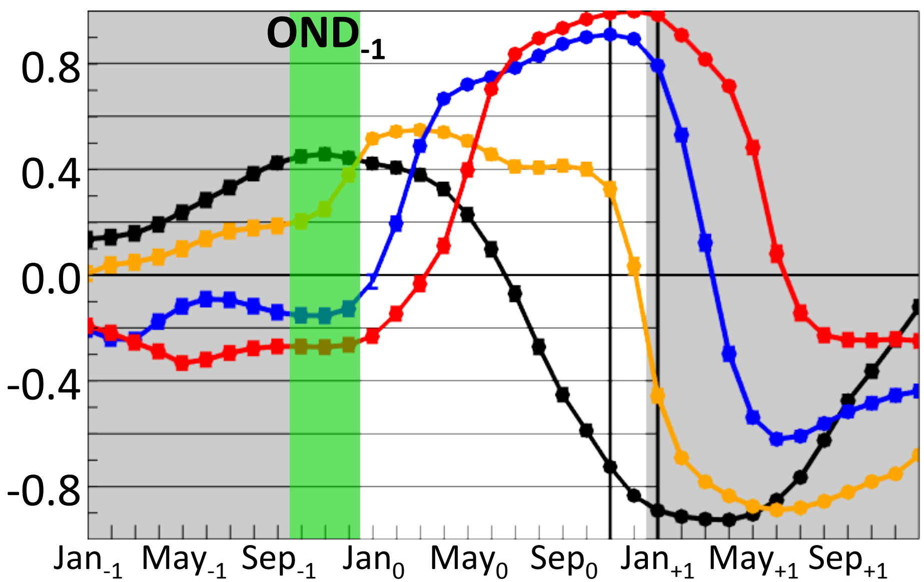
La Niña events: 0.87 (0.76 to 0.99) (obs: 0.40 to 4.07)

El Niño events: 0.11 (0.05 to 0.16) (obs: -0.21 to 0.66)

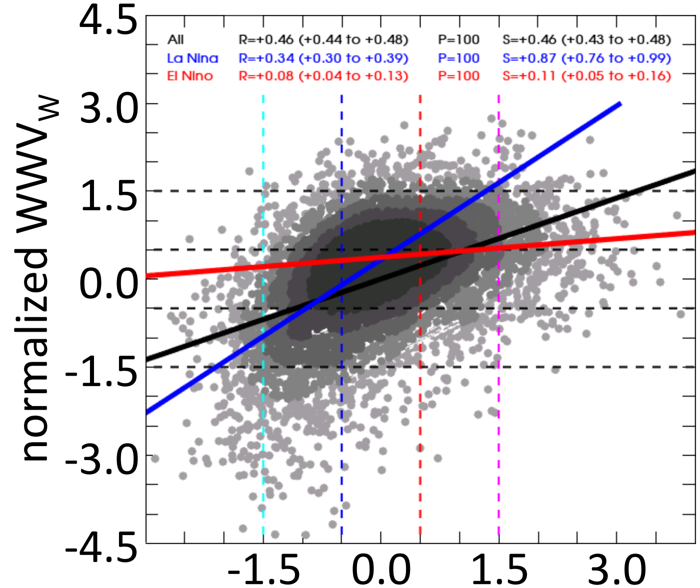
➔ strong nonlinearity

➔ weaker uncertainties (1800 La Niña events, 1607 El Niño events)

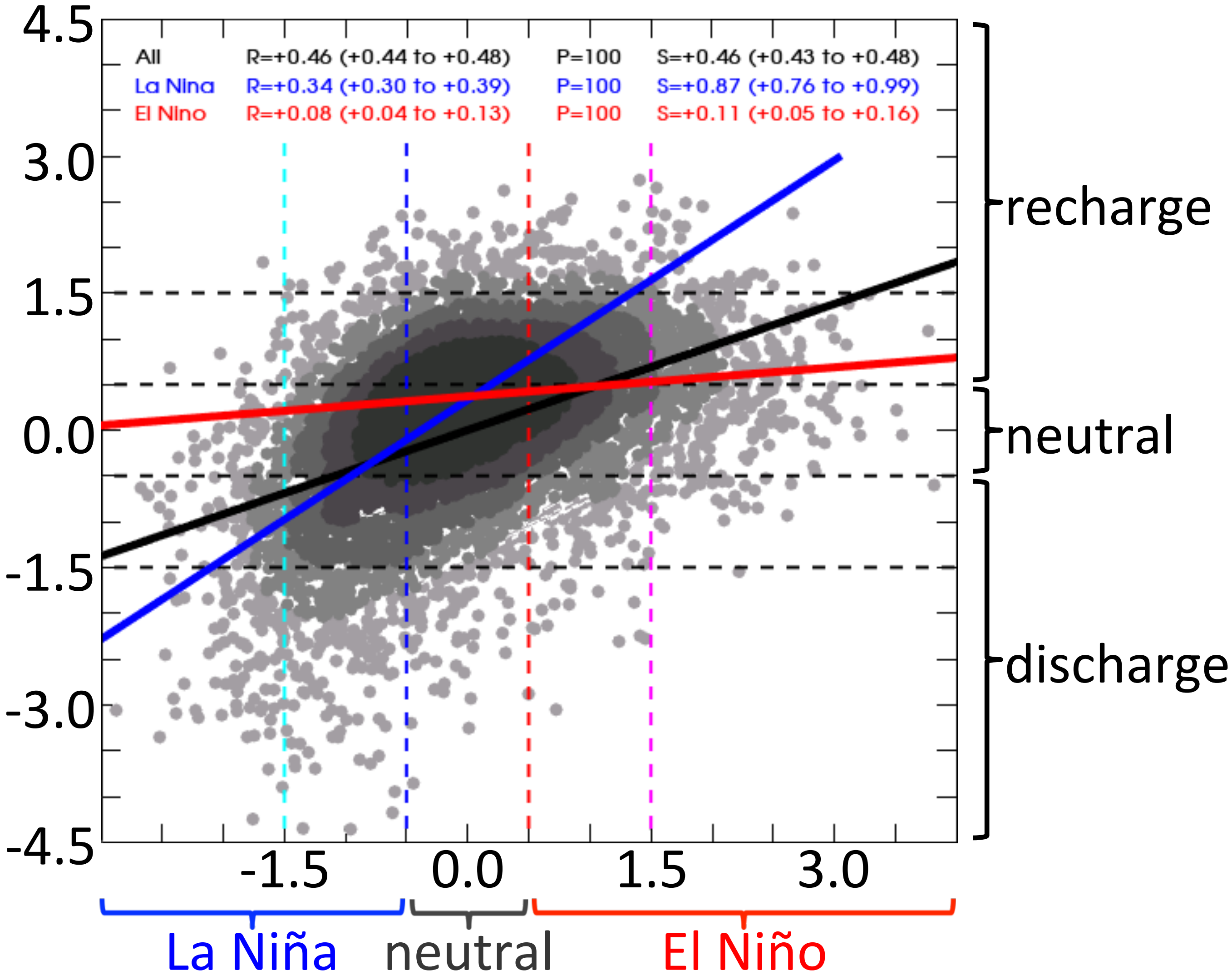
MME



MME

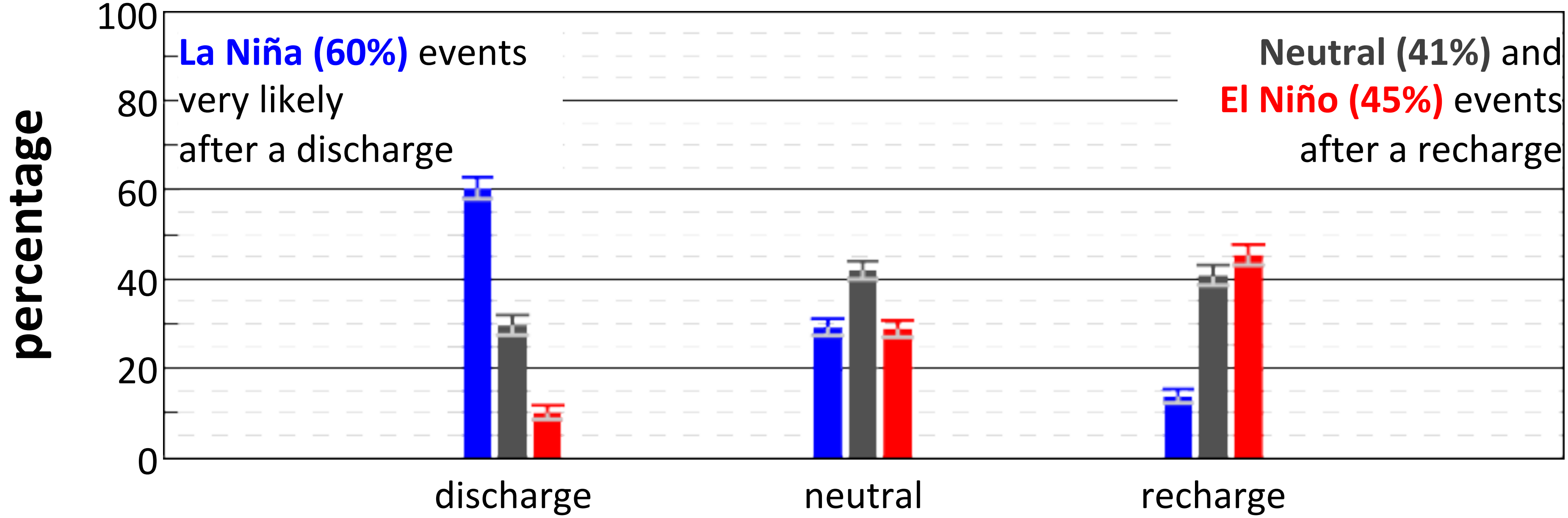


Asymmetry & ENSO prediction?



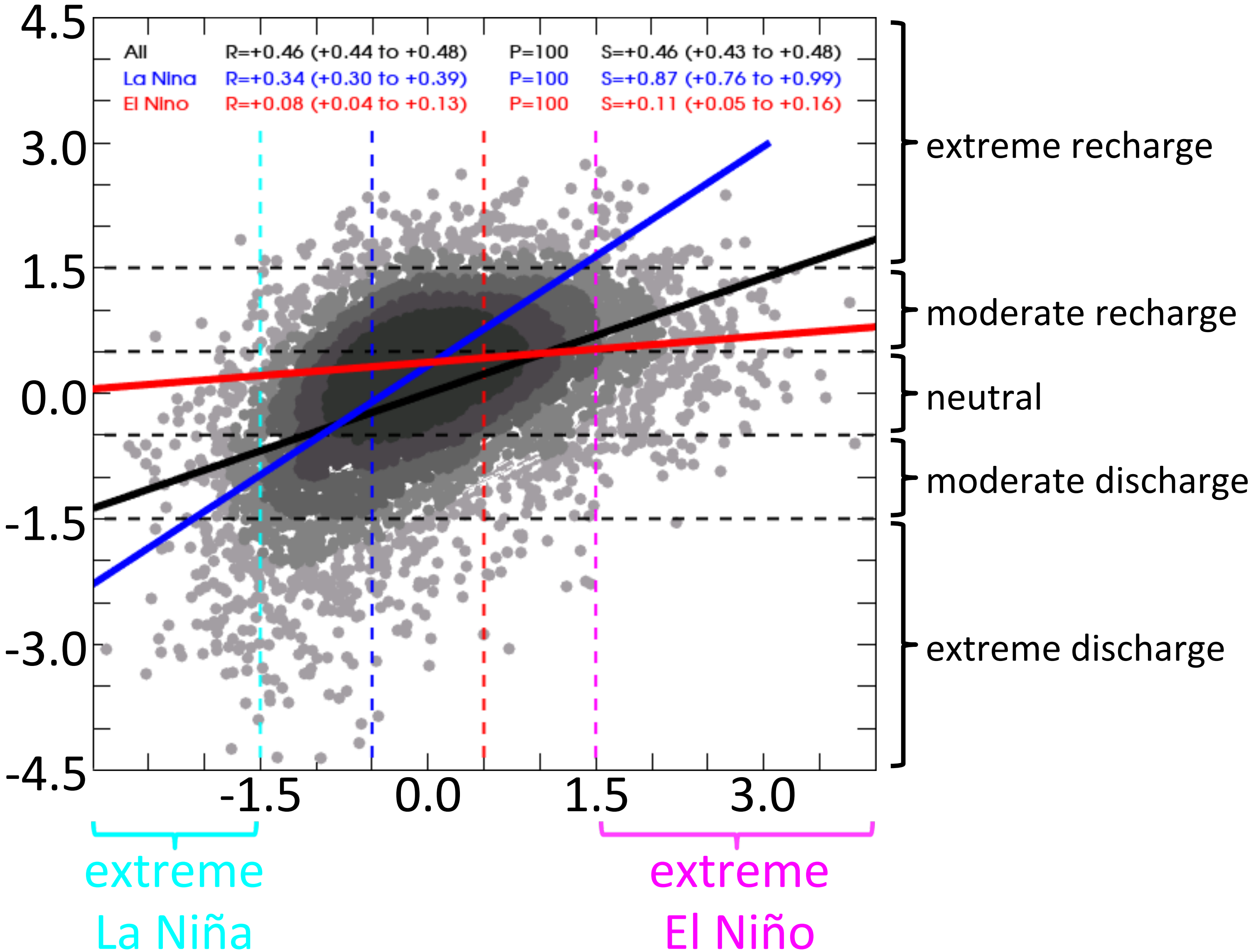
WWV_W: a precursor for ENSO occurrence

MME: probability of events 13 months after

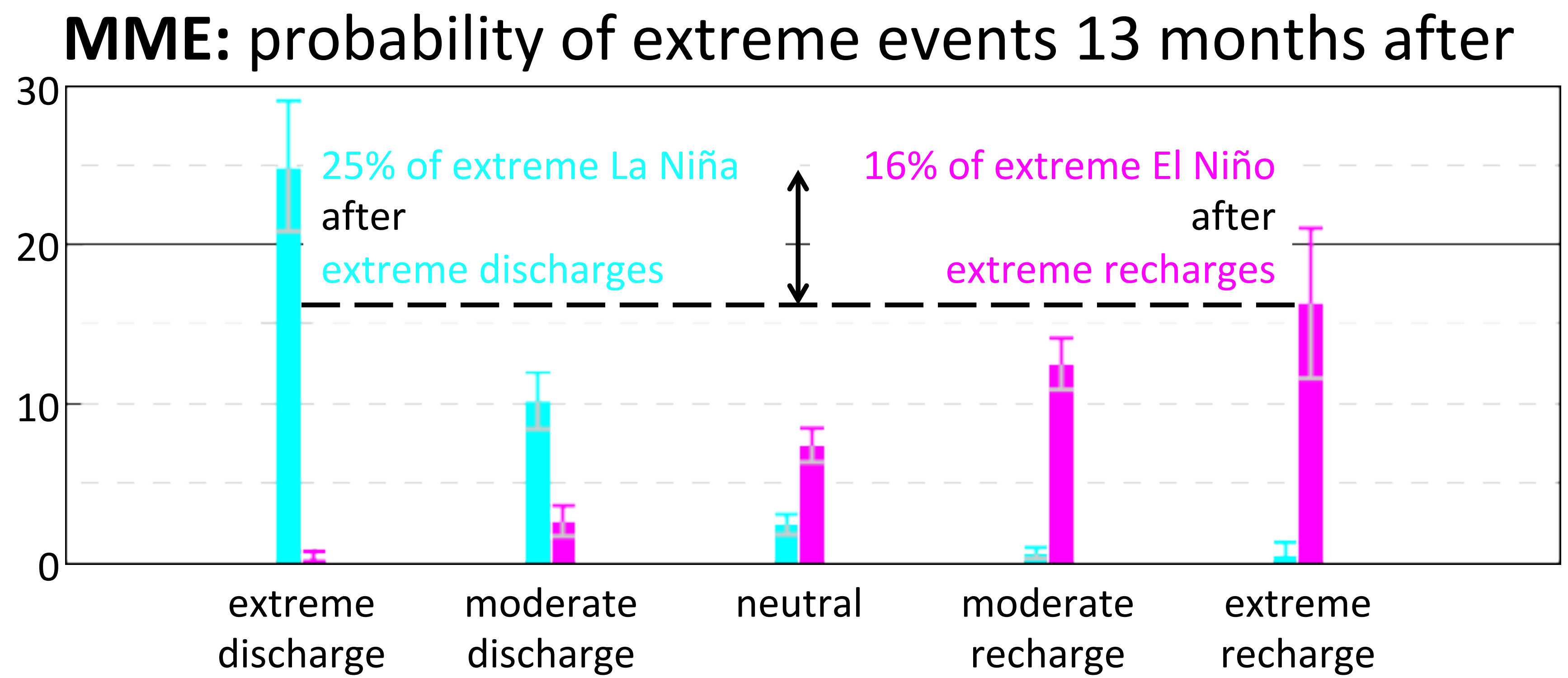


The discharge is a better predictor of La Niña events than the recharge for El Niño events

Asymmetry & ENSO prediction?



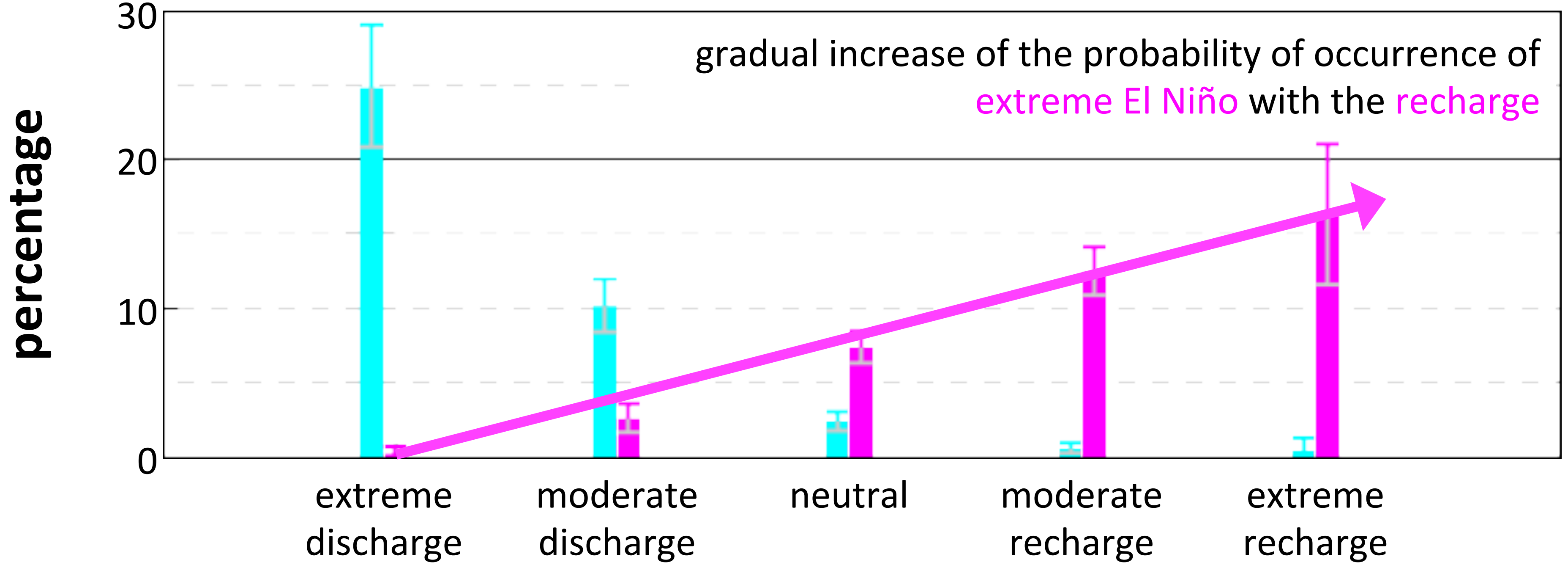
WWV_W: a precursor for ENSO amplitude



extreme La Niña events: SSTA < -1.5 STD SSTA > 1.5 STD :extreme El Niño events

WWV_W: a precursor for ENSO amplitude

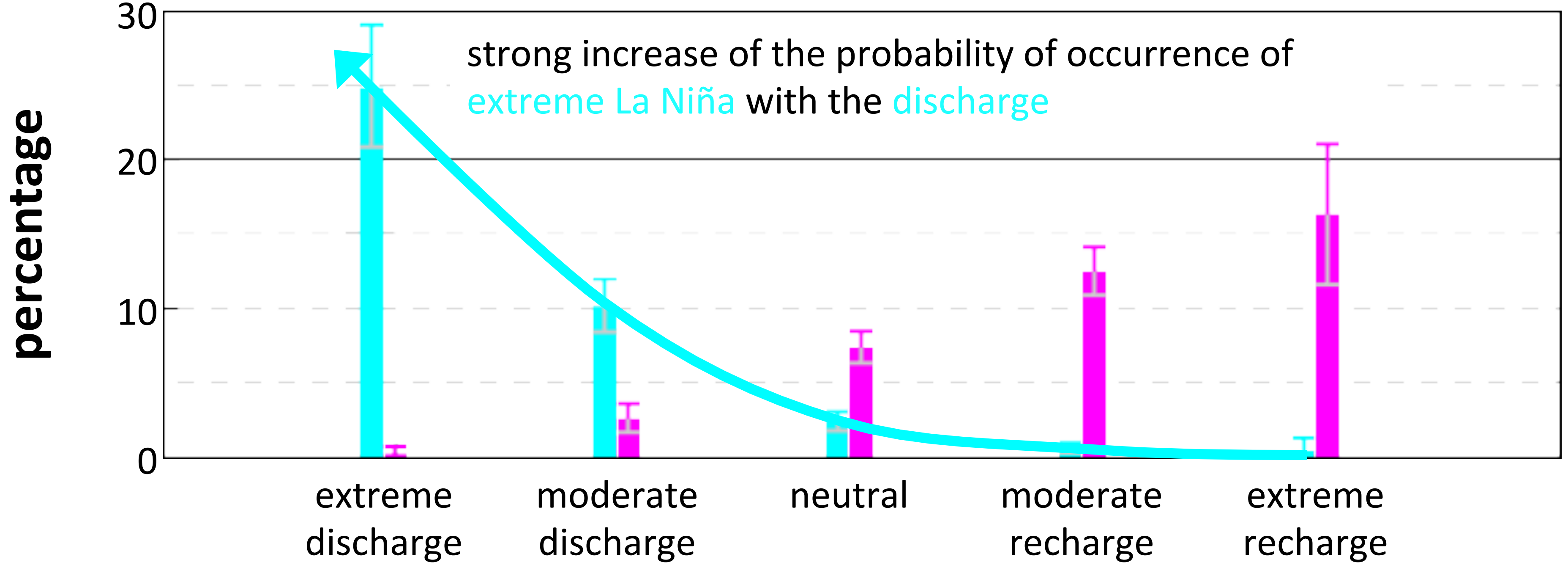
MME: probability of extreme events 13 months after



extreme La Niña events: SSTA < -1.5 STD **SSTA > 1.5 STD :extreme El Niño events**

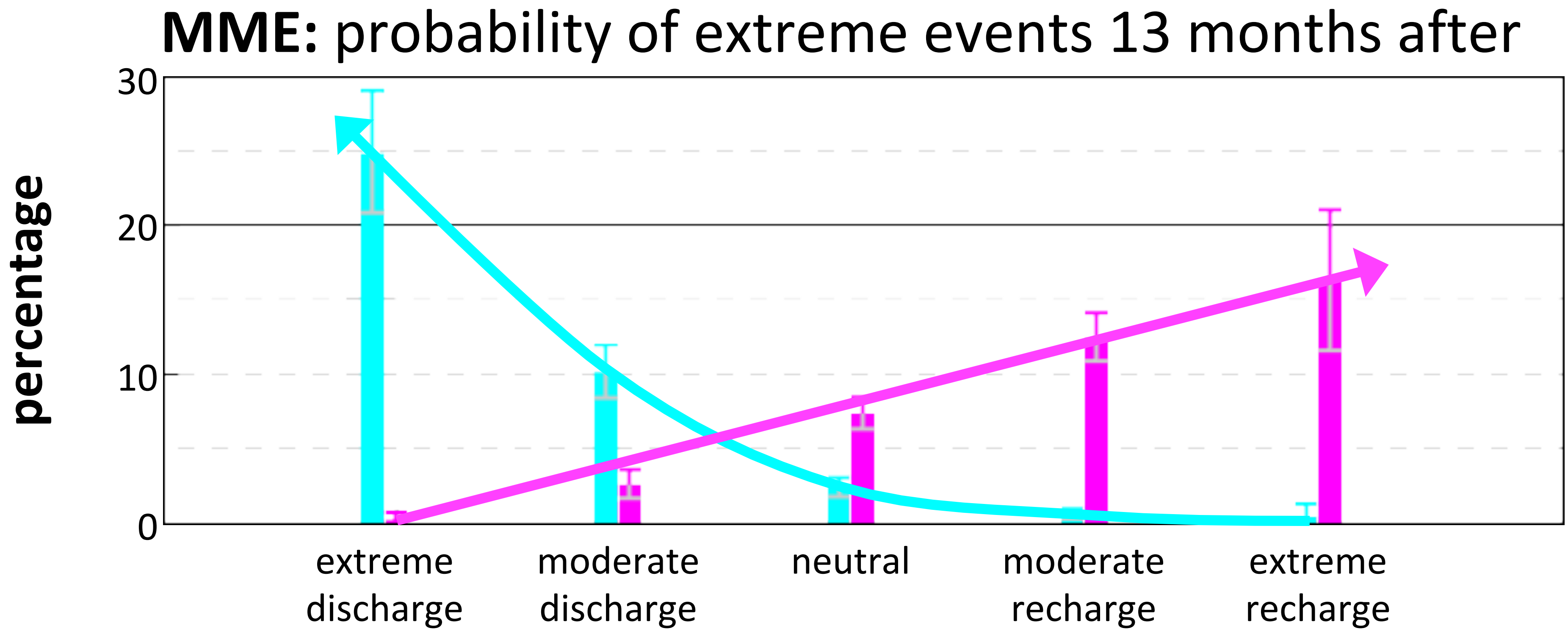
WWV_W: a precursor for ENSO amplitude

MME: probability of extreme events 13 months after



extreme La Niña events: **SSTA < -1.5 STD** **SSTA > 1.5 STD :**extreme El Niño events

WWV$_W$: a precursor for ENSO amplitude



The discharge's amplitude is a better predictor of La Niña events' amplitude
than the recharge's amplitude for El Niño events' amplitude

How can we explain this asymmetry?

1) Preconditioning ($year_{-1}$)

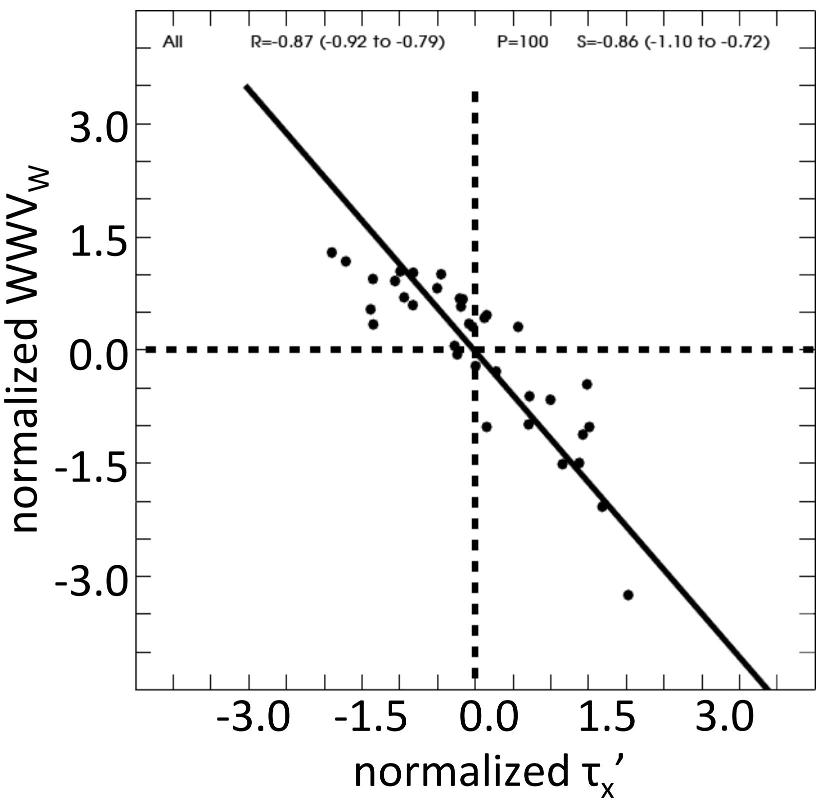
2) Triggering (spring)

3) Amplification (summer-fall)

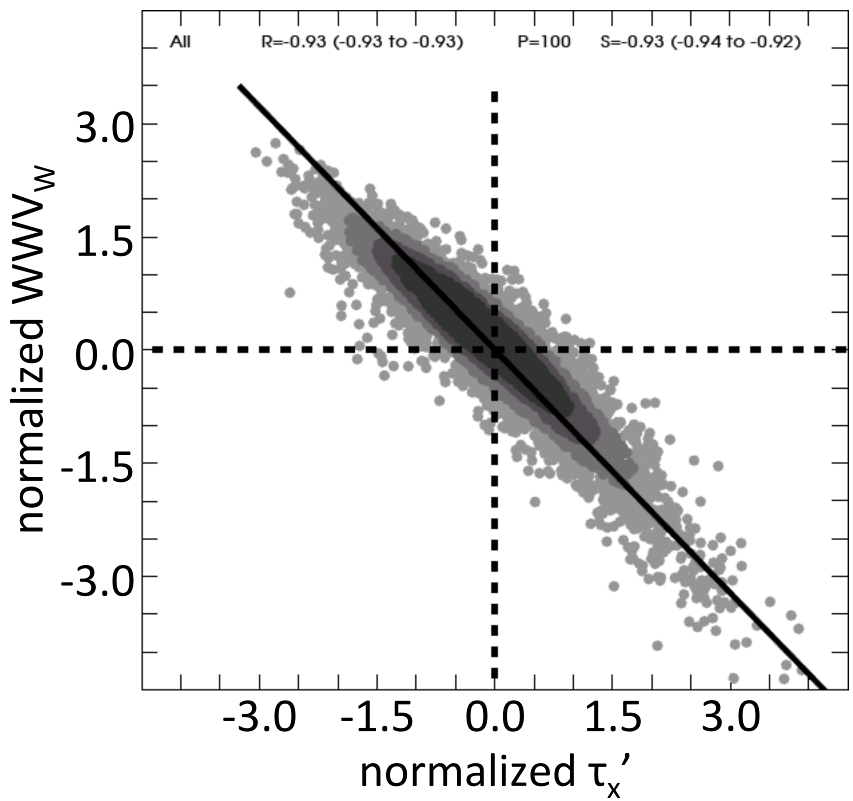
1) Preconditioning (year$_{-1}$)

- Izumo et al. (2018): WWV_W related to Rossby waves ➔ integral of zonal wind stress anomalies (τ_x) over the equatorial Pacific and the previous 10 months (τ_x')

OBS

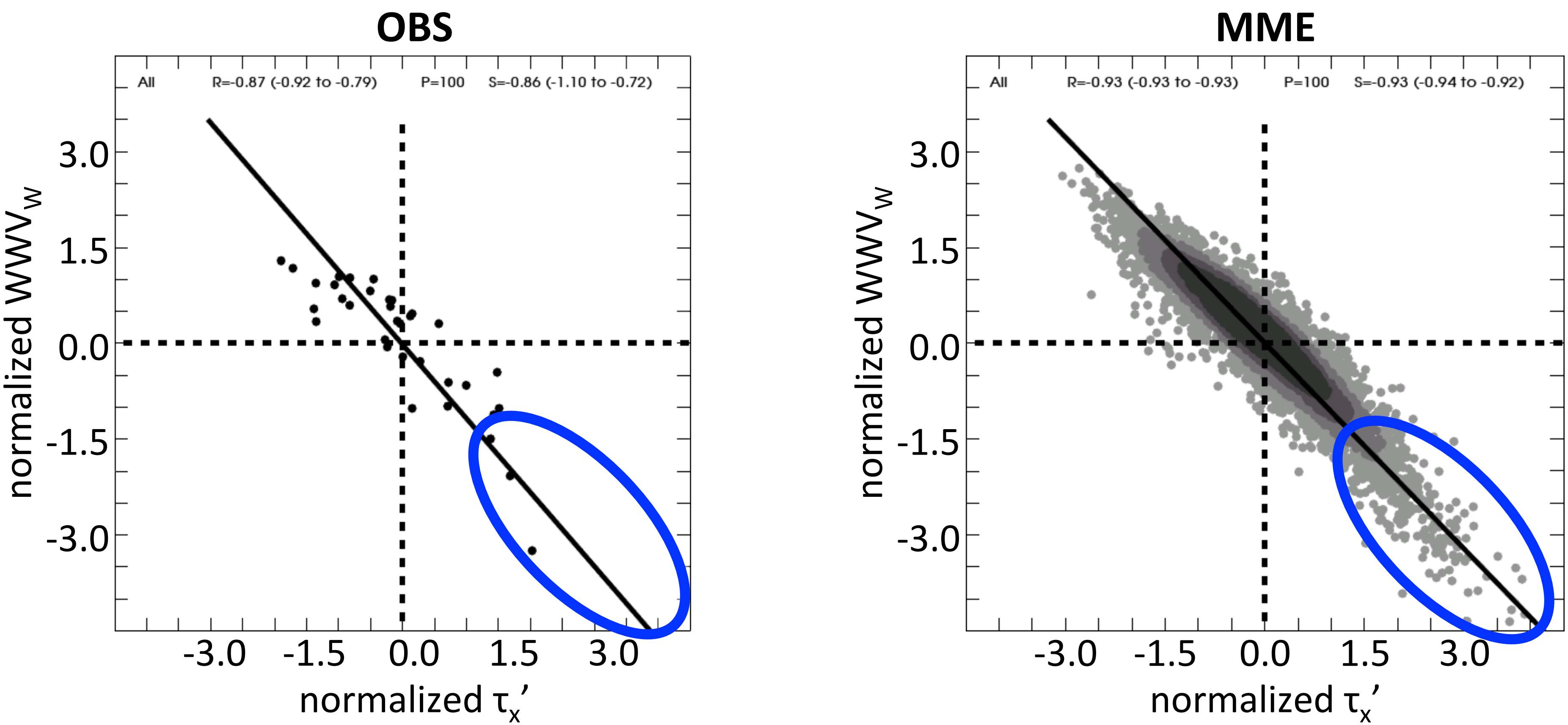


MME



1) Preconditioning (year$_{-1}$)

- Stronger El Niño than La Niña events => stronger positive zonal wind stress => stronger discharge



How can we explain this asymmetry?

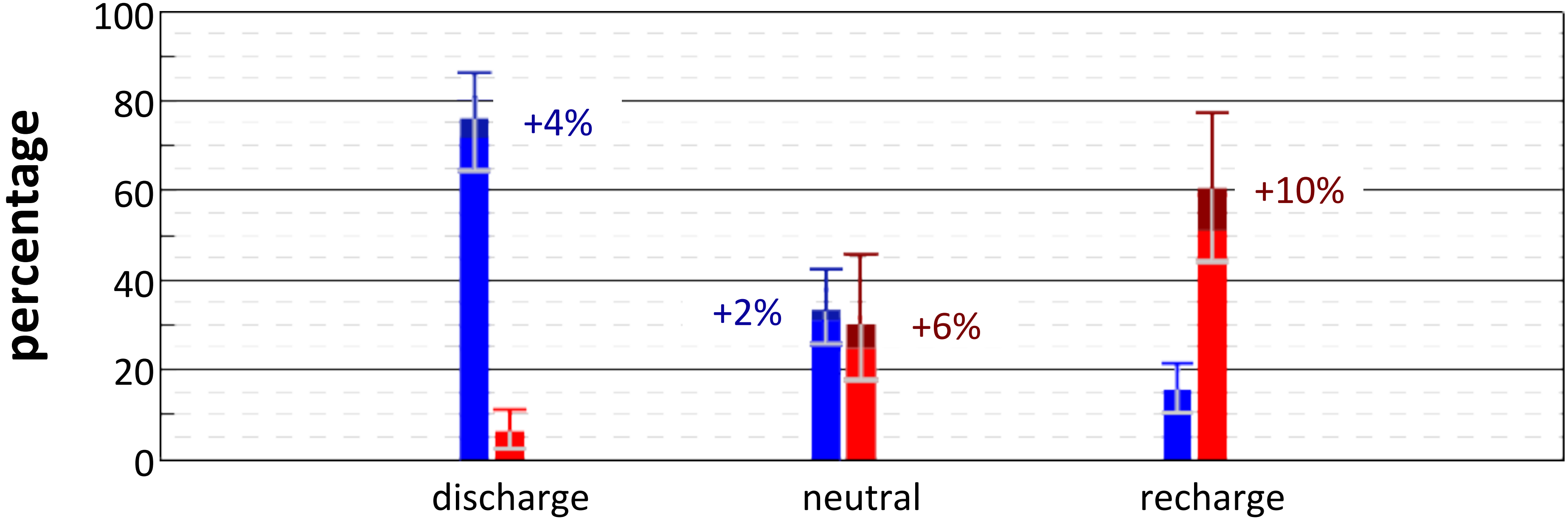
1) Preconditioning ($year_{-1}$)
   - Strong El Niño events => strong positive τ_x => strong discharge => strong preconditioning for La Niña events
2) Triggering (spring)
3) Amplification (summer-fall)

How can we explain this asymmetry?

1) Preconditioning ($year_{-1}$)
   - Strong El Niño events => strong positive τ_x => strong discharge => strong preconditioning for La Niña events
2) Triggering (spring)
   - strong WWE can trigger an event, like in 1997 or 2015 (e.g., Lengaigne et al. 2004, Fedorov et al. 2015)
3) Amplification (summer-fall)

2) Triggering (spring)

CNRM-CM5: probability of events WWV_W + wind event



WWV_W + EWE = La Niña WWV_W + WWE = El Niño

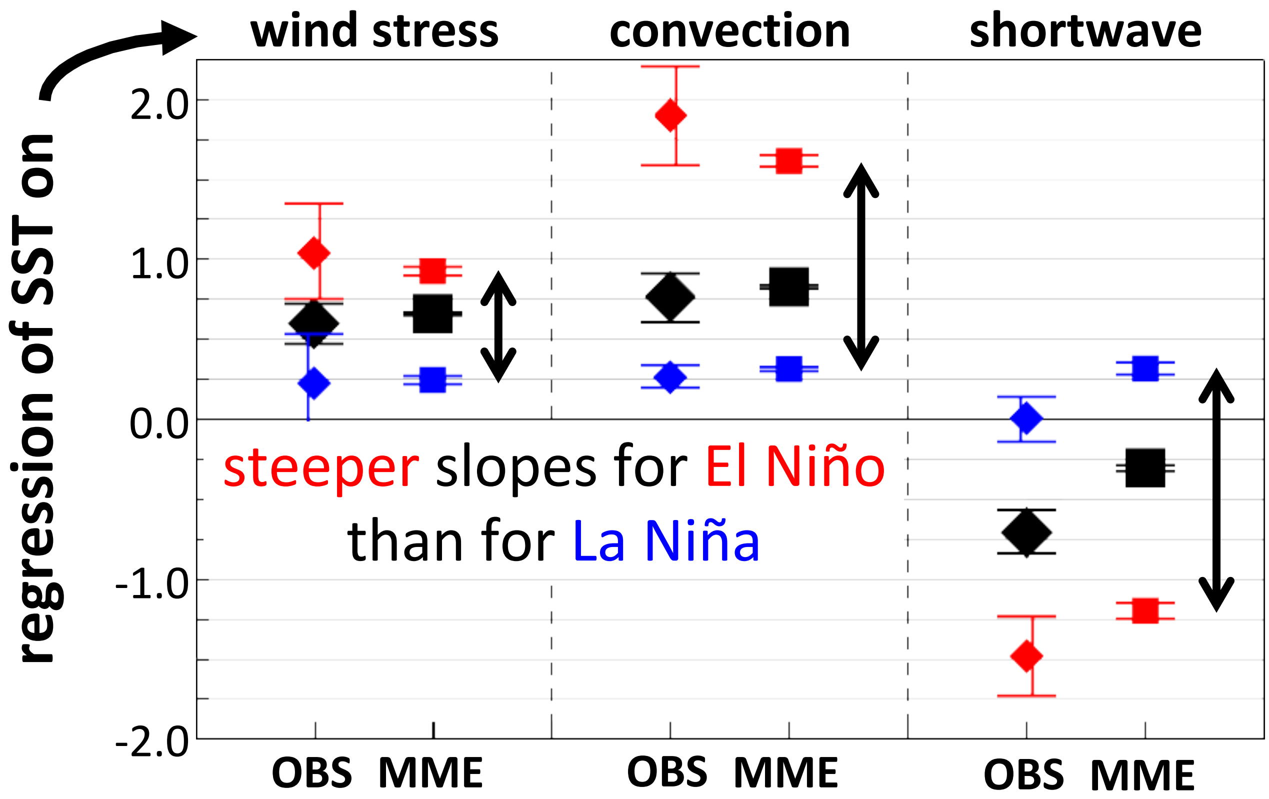
La Niña events: SSTA < -0.5 STD **Neutral** **SSTA > 0.5 STD :El Niño events**

How can we explain this asymmetry?

1) Preconditioning (year$_{-1}$)
   - Strong El Niño events => strong positive τ_x => strong discharge => strong preconditioning for La Niña events
2) Triggering (spring)
   - strong WWE can trigger an event, like in 1997 or 2015 (e.g., Lengaigne et al. 2004, Fedorov et al. 2015)
3) Amplification (summer-fall)

3) Amplification (summer-fall)

- Collocated linear regression in Niño3.4

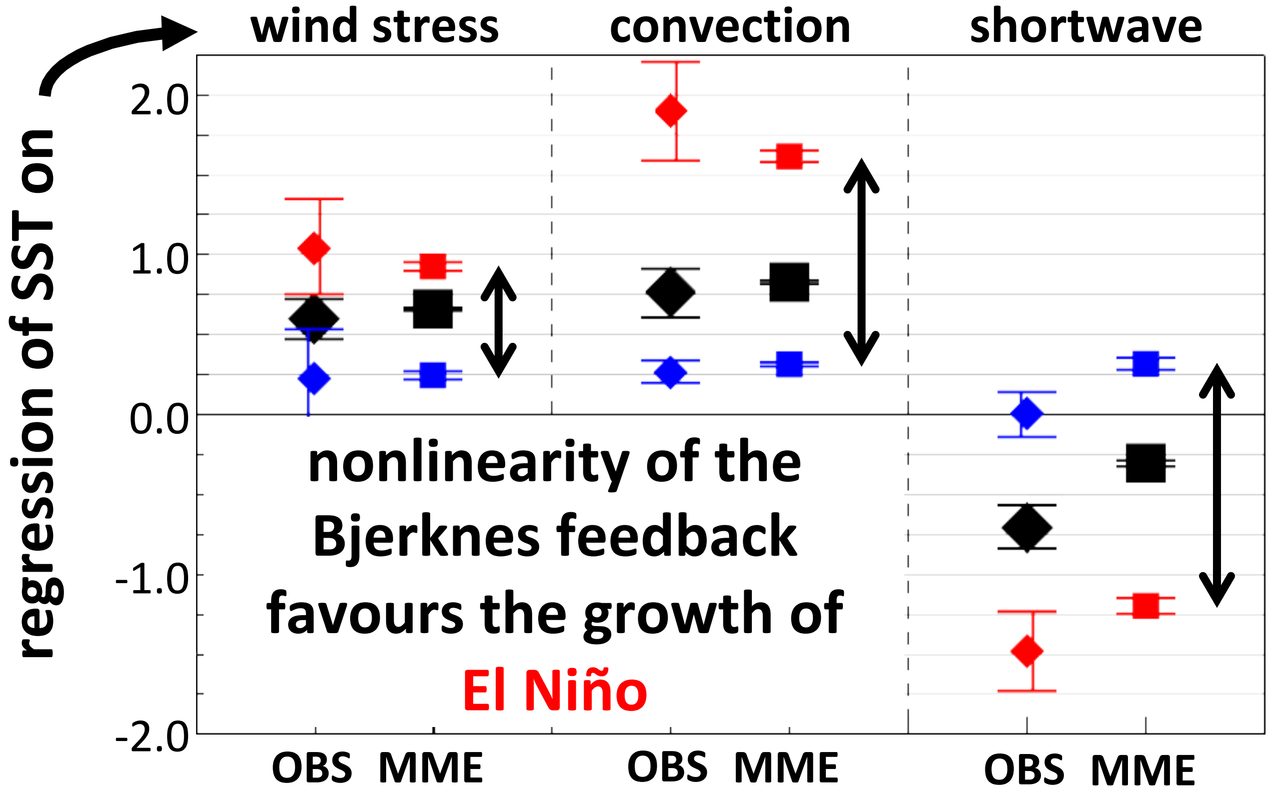


non-linearities in the atmospheric response to SST anomalies
(e.g., Graham et al. 1987, Bellenger et al. 2014, Takahashi et al. 2016)

La Niña events **All years** **El Niño events**

3) Amplification (summer-fall)

- Collocated linear regression in Niño3.4



La Niña events

All years

El Niño events

How can we explain this asymmetry?

1) Preconditioning ($year_{-1}$)
   - Strong El Niño events => strong positive τ_x => strong discharge => strong preconditioning for La Niña events
2) Triggering (spring)
   - strong WWE in spring can trigger an event, like in 1997 or 2015 (e.g., Lengaigne et al. 2004, Fedorov et al. 2015)
3) Amplification (summer-fall)
   - nonlinear Bjerknes feedback (e.g., Takahashi et al. 2016)
   - subsequent WWEs (e.g., Puy et al. 2017)

➢ Others? NDH? biological feedback? ...

Conclusions

Asymmetry in the WWV_W–ENSO relationship

➔ reproduced by CMIP5 models (at least the 11 used)

➔ WWV_W is a better predictor of both La Niña event's occurrence and amplitude than El Niño event's occurrence and amplitude

➔ La Niña = stronger preconditioning + weaker atmospheric processes

➔ El Niño = weaker preconditioning + stronger atmospheric processes

➔ hypothesis will be tested through modeling studies

References

Bellenger H, Guilyardi E, Leloup J, Lengaigne M, Vialard J (2014) ENSO representation in climate models: from CMIP3 to CMIP5. Clim Dyn 42(7):1999-2018. doi: 10.1007/s00382-013-1783-z

Fedorov AV, Hu S, Lengaigne M, Guilyardi E (2015) The impact of westerly wind bursts and ocean initial state on the development, and diversity of El Niño events. Clim Dyn 44(5):1381-1401. doi: 10.1007/s00382-014-2126-4

Graham NE, Barnett TP (1987) Sea surface temperature, surface wind divergence, and convection over tropical oceans. Science 238(4827):657-659. doi: 10.1126/science.238.4827.657

Izumo T, Lengaigne M, Vialard J, Suresh I, Planton Y (2018) On the physical interpretation of the lead relation between the Warm Water Volume and the El Niño Southern Oscillation. Submitted to Climate Dynamics

Lengaigne et al. (2004) Triggering of El Niño by Westerly Wind Events in a coupled general circulation model. Clim Dyn 23:601-620. doi: 10.1007/s00382-004-0457-2

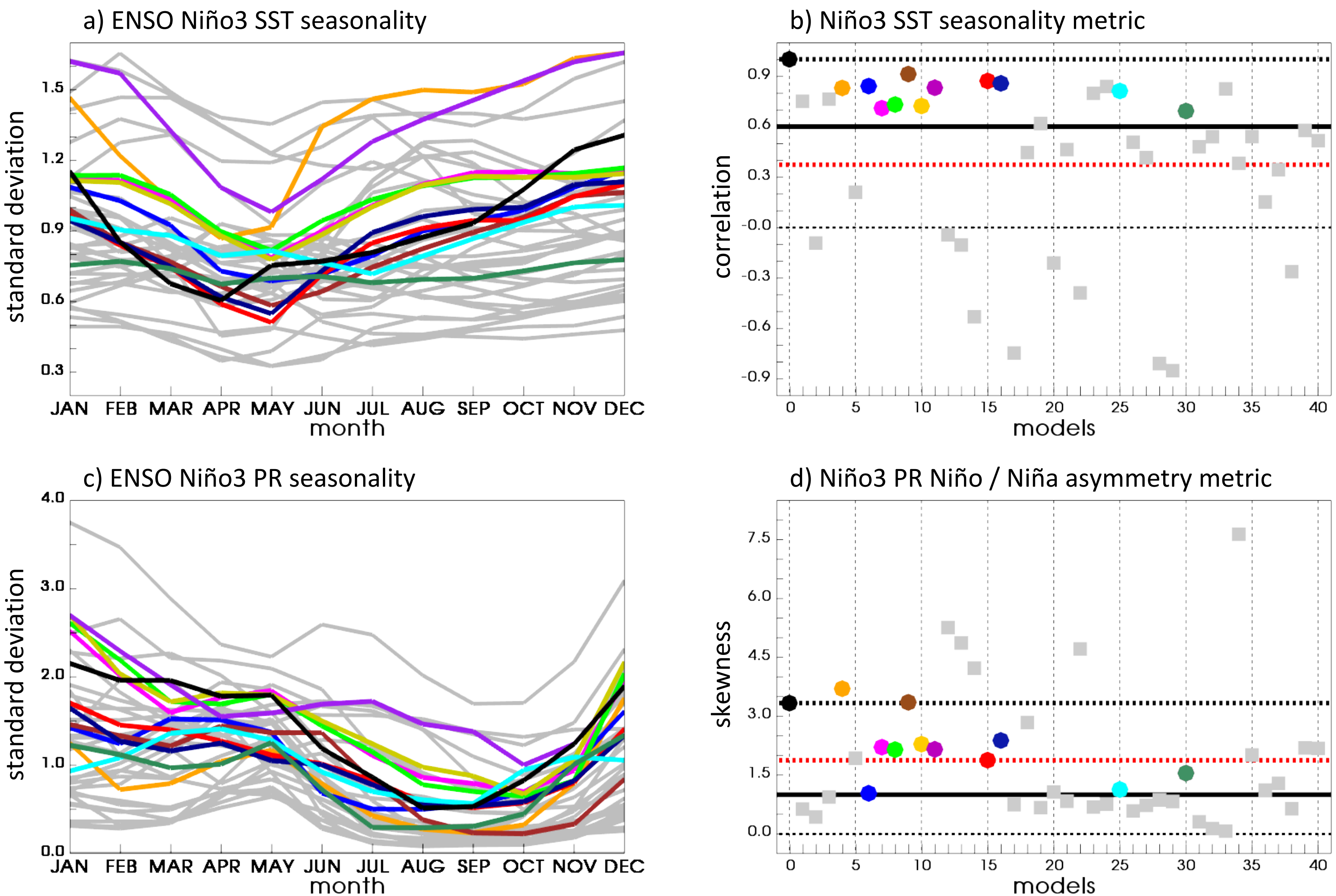
Meinen C and McPhaden MJ (2000) Observations of warm water volume changes in the equatorial Pacific and their relationship to El Niño and La Niña. J Clim 13(20):3551-3559. doi: 10.1175/1520-0442(2000)013<3551:Oowwvc>2.0.Co;2

Puy M, Vialard J, Lengaigne M, Guilyardi E, DiNezio PN, Voldoire A, Balmaseda M, Madec G, Menkes C, McPhaden MJ (2017) Influence of Westerly Wind Events stochasticity on El Niño amplitude: the case of 2014 vs. 2015. Clim Dyn. doi: 10.1007/s00382-017-3938-9

Takahashi K, Dewitte B (2016) Strong and moderate nonlinear El Niño regimes. Clim Dyn 46(5):1627-1645. doi: 10.1007/s00382-015-2665-3

Supplementary

S1: model selection



S1: model selection

- selection based on two criteria:

1) accurate representation of ENSO seasonality, with a peak of variability in boreal winter

   (correlation obs-model of the Niño3 SSTA standard deviation > 0.6)

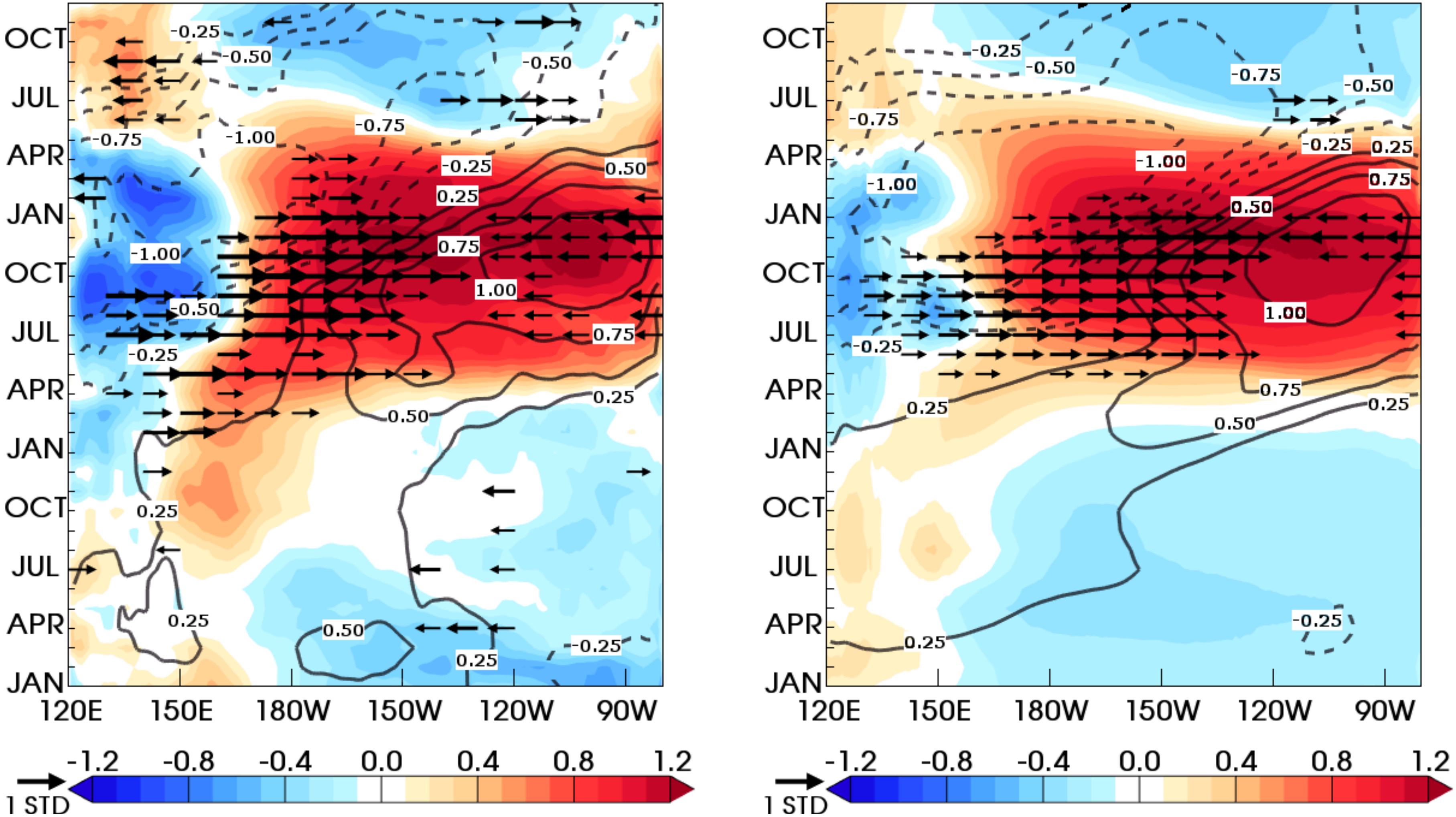
2) ability to simulate strong El Niño events (defined as massive precipitations in the eastern Pacific)

   (skewness of the Niño3 PRA in DJF >1)

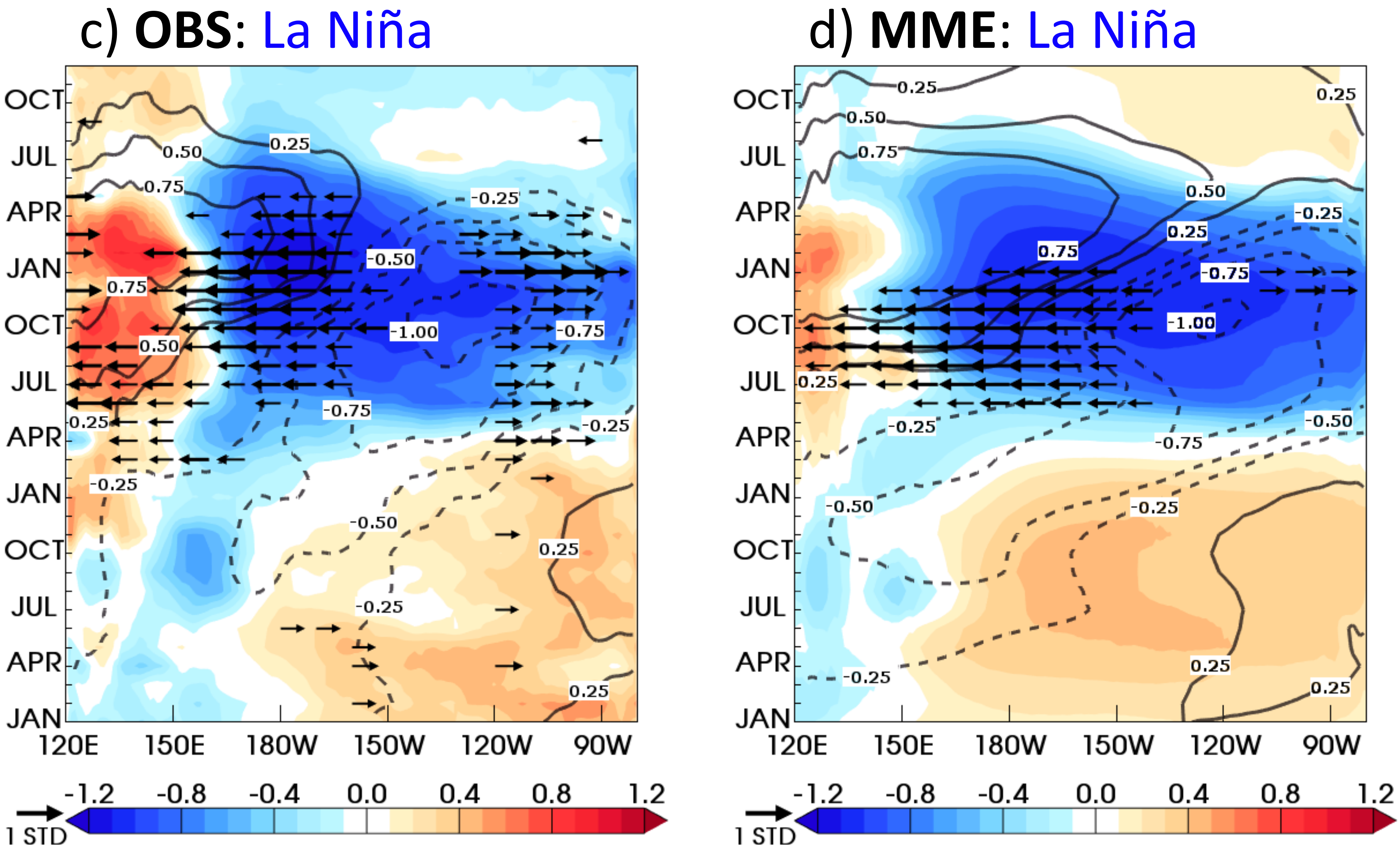
00. Observations	12. CMCC-CESM	**24. HadCM3**	36. MPI-ESM-LR
01. ACCESS1-0	13. CMCC-CM	25. HadGEM2-AO	37. MPI-ESM-MR
02. ACCESS1-3	14. CMCC-CMS	26. HadGEM2-CC	38. MPI-ESM-P
03. bcc-csm1-1	**15. CNRM-CM5**	27. HadGEM2-ES	39. MRI-ESM-P
04. bcc-csm1-1-m	**16. CNRM-CM5-2**	28. inmcm4	40. NorESM1-M
05. BNU-ESM	16. CSRO-Mk3-6-0	29. IPSL-CM5A-LR	41. NorESM1-ME
06. CanESM2	17. FGOALS-s2	30. IPSL-CM5A-MR	
07. CCSM4	18. FIO-ESM	**31. IPSL-CM5B-LR**	
08. CESM1-BGC	19. GFDL-CM3	32. MIROC-ESM	
09. CESM1-CAM5	20. GFDL-ESM2G	33. MIROC-ESM-	
10. CESM1-	21. GFDL-ESM2M	CHEM	
FASTCHEM	22. GISS-E2-H-CC	34. MIROC4h	
11. CESM1-WACCM	23. GISS-E2-R-CC	35. MIROC5	

S2: MME evaluation

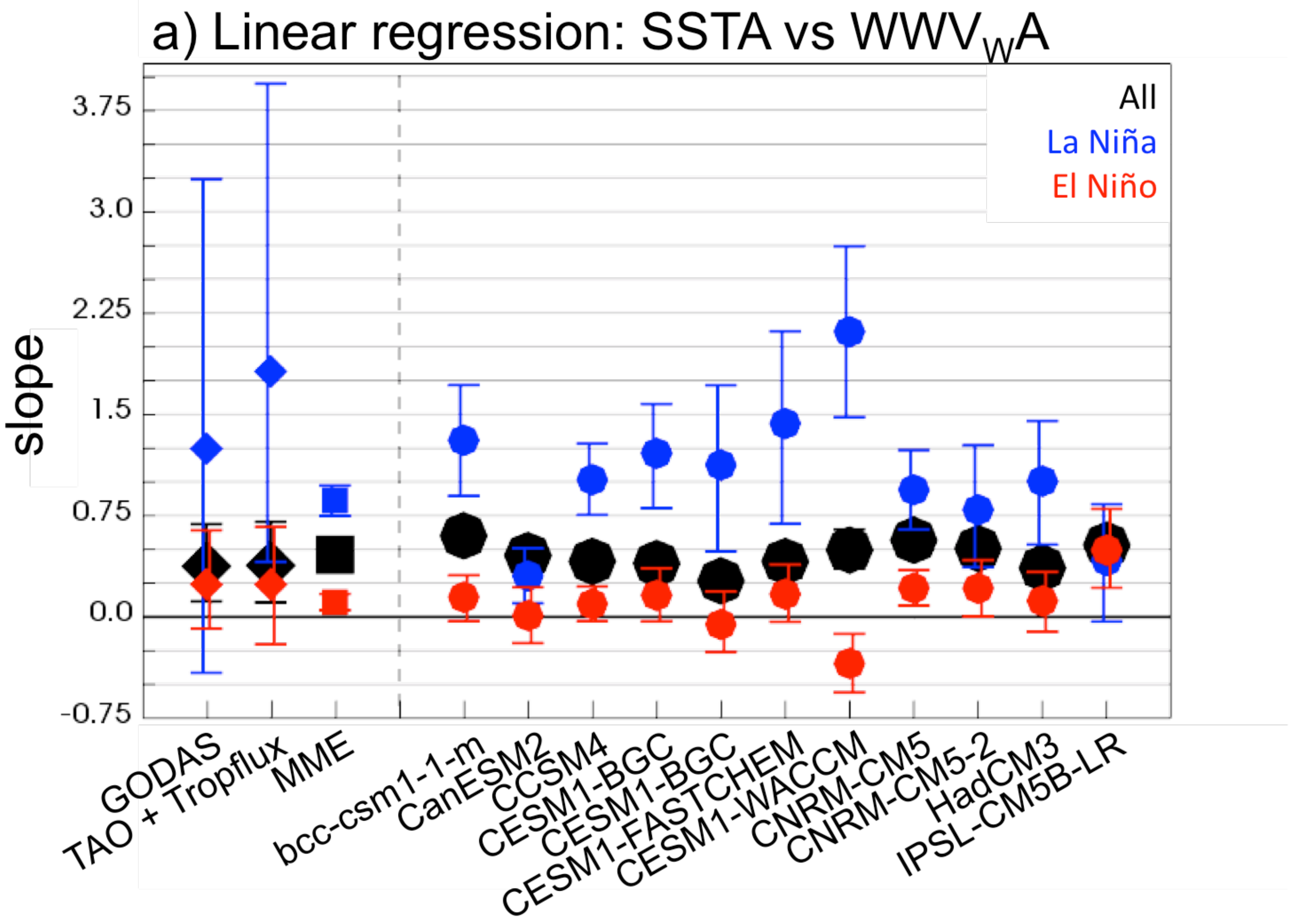
a) **OBS**: El Niño   b) **MME**: El Niño



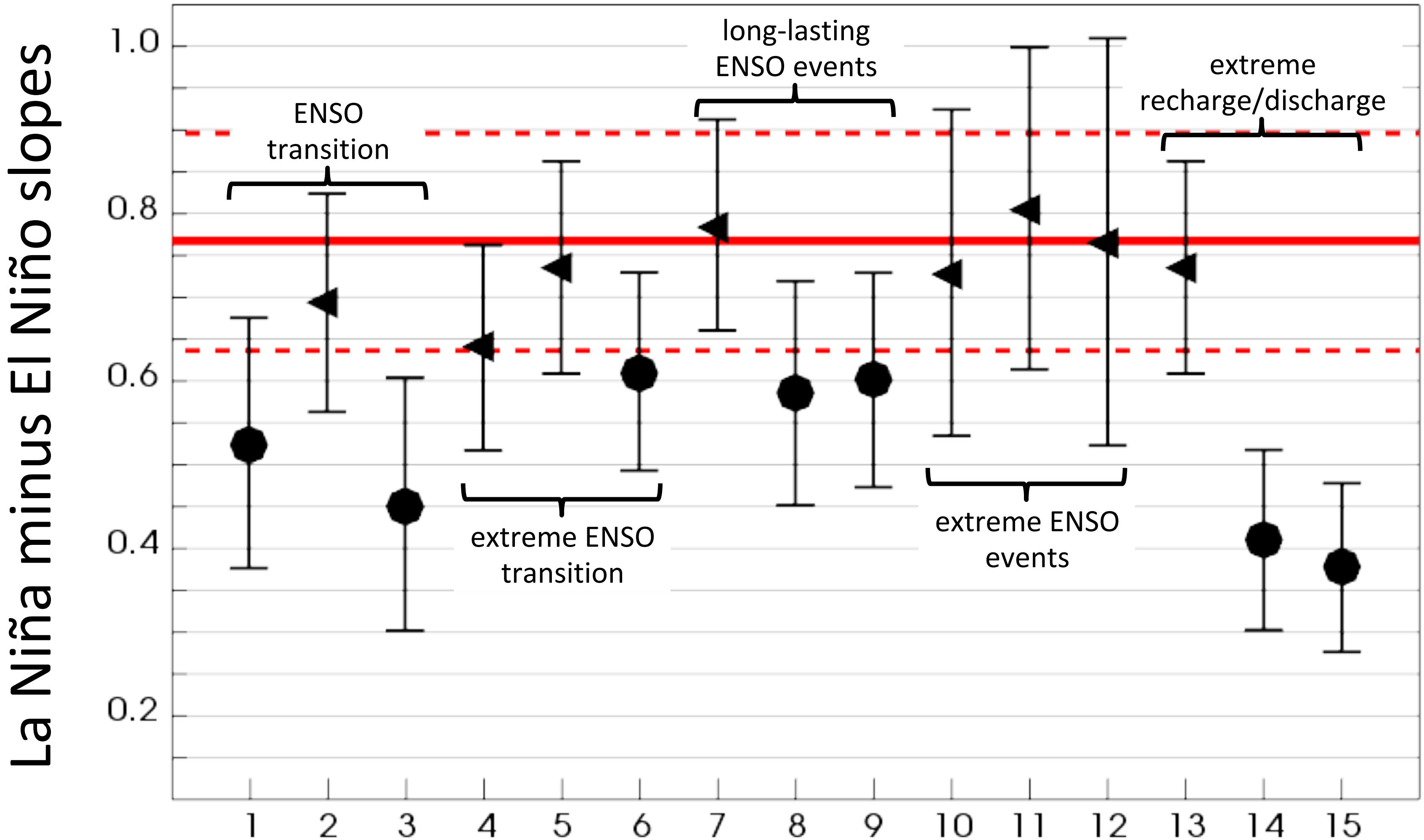
S2: MME evaluation



S3: ENSO-WWV_W asymmetry intercomparaison



Impact of ENSO transition/extreme/long-lasting events and extreme recharge/discharge



1. no transition El Niño to La Niña
2. no transition La Niña to El Niño
3. 1 & 2

4. no transition extreme El Niño to La Niña
5. no transition extreme La Niña to El Niño
6. 4 & 6

7. no long-lasting El Niño
8. no long-lasting La Niña
9. 7 & 8

10. no extreme El Niño
11. no extreme La Niña
12. 10 & 11

13. no extreme recharge
14. no extreme discharge
15. 13 & 14